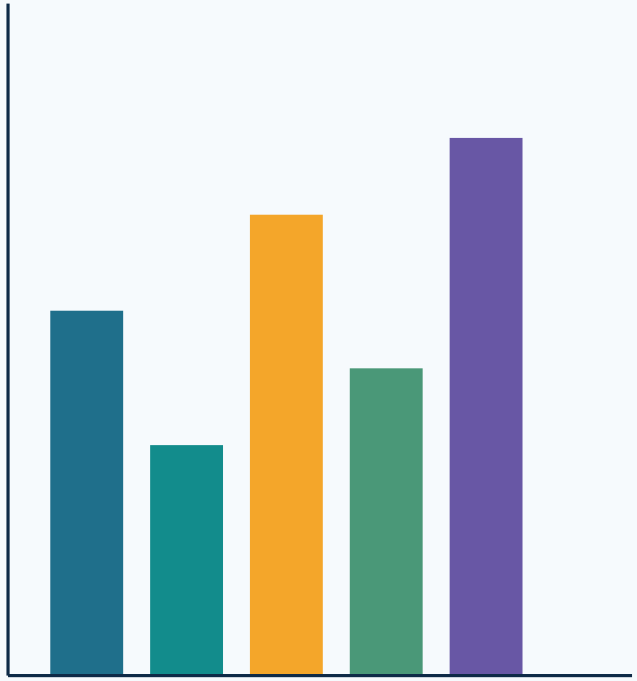
LECTURE SLIDES

Introduction to Quantitative Data Analysis

A student-friendly university lecture on preparing, describing, testing, interpreting, and reporting numerical research data.

DATA → ANALYSIS → EVIDENCE



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ROADMAP

Lecture Overview

This lecture explains how researchers move from numerical data to evidence-based interpretation.

Foundations
Terms, variables, scales, and research cycle.

Descriptive analysis
Summaries, distributions, and visual patterns.

Inferential analysis
Samples, hypotheses, uncertainty, and tests.

Applications
Examples, ethics, mistakes, and best practices.

BY THE END OF THIS LECTURE

Learning Objectives

Define quantitative data analysis and explain its role in research.

Distinguish key data types, variables, and measurement scales.

Summarize numerical data using descriptive statistics and graphs.

Explain the logic of hypotheses, p-values, confidence intervals, and effect sizes.

Select suitable statistical techniques for common research questions.

Identify ethical issues, limitations, and common mistakes.

Understand

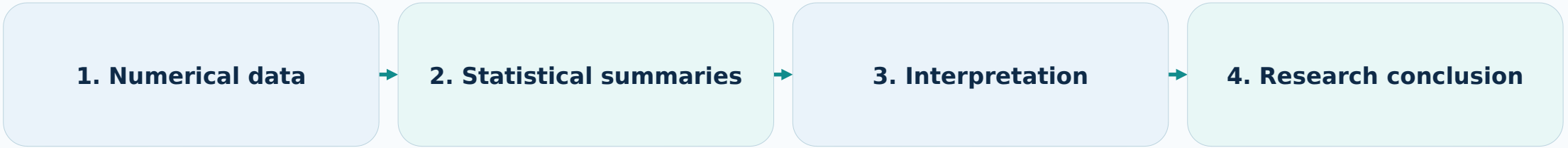
Analyze

Interpret

Report

Introduction

Quantitative data analysis is the systematic examination of numerical data to describe patterns, test relationships, compare groups, and support research conclusions.



It connects research questions to measurable evidence.

It helps researchers identify patterns that are difficult to see in raw data.

It supports transparent, replicable, and evidence-based decision making.

CORE VOCABULARY

Key Definitions

Term	Student-friendly meaning	Example
Dataset	Organized collection of observations and variables	Survey responses from 300 students
Variable	A characteristic that can take different values	Age, income, test score
Case / unit	The person, event, group, or object being measured	One student or one company
Statistic	Numerical summary from sample data	Mean satisfaction score
Parameter	Numerical value describing the whole population	True average income of all graduates

Background and Context

Quantitative analysis grew from measurement, probability, mathematics, and empirical research traditions. Today it is used across disciplines to evaluate evidence systematically.

Measurement tradition
Abstract concepts are translated into indicators that can be counted or measured.

Statistical tradition
Probability helps researchers reason from samples to wider populations.

Computational tradition
Modern software helps clean, visualize, model, and report data.

Good quantitative analysis requires technical skill and methodological judgment.

LOGICAL SEQUENCE

Main Concepts in Quantitative Analysis

Measurement turns concepts into variables and scores.

Data quality checks whether values are complete, accurate, and consistent.

Descriptive analysis summarizes patterns in the observed data.

Inferential analysis estimates uncertainty and supports conclusions about populations.

Interpretation connects statistical output to theory, context, and limitations.

Types of Quantitative Data

Scale	Meaning	Examples	Common summaries
Nominal	Categories with no natural order	Region, department	Counts, percentages, mode
Ordinal	Ordered categories; unequal gaps	Likert ratings, rank	Median, frequencies
Interval	Equal gaps; no true zero	Temperature °C, standardized score	Mean, SD
Ratio	Equal gaps with true zero	Age, income, time	Mean, SD, ratios

The measurement scale influences which summaries, graphs, and tests are appropriate.

Variables and Their Roles

Independent variable
A factor or predictor expected to influence an outcome. Example: teaching method.

Dependent variable
The outcome being explained or measured. Example: exam score.

Control variable
A factor adjusted for to reduce alternative explanations. Example: prior GPA.

Data Sources and Study Designs

COMMON DATA SOURCES

Surveys and questionnaires

Experiments and interventions

Administrative records

Digital traces and system logs

Observational measurements

DESIGN FEATURES TO NOTE

Cross-sectional or longitudinal

Experimental or non-experimental

Independent or paired groups

Sample size and sampling method

Level of measurement and missingness

Descriptive Statistics

Descriptive statistics organize and summarize observed data. They describe the sample but do not prove that the pattern exists in the wider population.

Purpose	Common statistics	Question answered
Central tendency	Mean, median, mode	What is a typical value?
Variability	Range, variance, standard deviation, IQR	How spread out are values?
Position	Percentiles, z-scores	Where does a case stand?
Shape	Skewness, kurtosis, distribution plots	Is the distribution unusual?

Visualizing Quantitative Data

Bar charts compare categories or groups.

Histograms show distributions of continuous variables.

Boxplots compare medians, spread, and outliers.

Scatterplots examine relationships between two numerical variables.

Line charts show change over time.

Mini visualization gallery

Good graphs reveal structure; poor graphs can distort meaning.

Distributions, Outliers, and Normality

DISTRIBUTION CHECKS

Look at histograms and boxplots.

Check whether values are symmetrical or skewed.

Identify outliers and unusual clusters.

Compare mean and median when skew is strong.

WHY IT MATTERS

Some tests assume approximate normality.

Extreme values can affect mean, SD, and regression.

Skewed data may need robust or nonparametric methods.

Outliers should be investigated, not automatically deleted.

Inferential Statistics

Inferential statistics use sample data to make cautious conclusions about a larger population while acknowledging uncertainty.

Confidence interval
A range of plausible values for a population parameter.

p-value
Probability of results at least as extreme if the null hypothesis were true.

Sampling error
Natural difference between a sample statistic and population parameter.

Hypothesis Testing

Element	Meaning	Example
Null hypothesis (H_0)	No effect, difference, or relationship	The method does not affect scores.
Alternative hypothesis (H_1)	An effect, difference, or relationship is expected	The method affects scores.
Significance level (α)	Decision threshold for statistical significance	$\alpha = .05$
Test statistic	Numerical value calculated from data	t, F, χ^2, r, coefficient
Decision	Reject or fail to reject H_0 using evidence and context	$p < .05$ may support rejecting H_0

“Fail to reject” does not mean “prove the null hypothesis is true.”

Statistical Significance and Effect Size

STATISTICAL SIGNIFICANCE

Asks whether the observed result is unlikely under the null hypothesis.

Strongly affected by sample size.

Often reported with p-values and confidence intervals.

Does not tell whether the result is practically important.

EFFECT SIZE

Describes the magnitude or strength of an effect.

Helps readers judge practical importance.

Examples include Cohen’s d, r, odds ratio, and R^2.

Should be interpreted with discipline norms and context.

Confidence Intervals

What it shows
A confidence interval estimates a plausible range for a population value, such as a mean difference or regression coefficient.

Why it helps
It communicates precision and uncertainty more clearly than a single estimate alone.

Narrow intervals usually indicate more precise estimates.

Wide intervals indicate greater uncertainty.

Intervals should be interpreted with study design, assumptions, and sample quality.

Common Statistical Tests

Research question	Typical data situation	Common test / method
Are two group means different?	Continuous outcome; two groups	Independent-samples t-test
Are more than two group means different?	Continuous outcome; 3+ groups	ANOVA
Are two categorical variables related?	Categories and counts	Chi-square test
Are two numerical variables associated?	Continuous or ordinal variables	Correlation
Can we predict an outcome?	Outcome + predictors	Regression analysis

Selecting an Appropriate Statistical Test

The test must match the research question and hypothesis.

The outcome variable is often the starting point for test selection.

The number of groups, paired/unpaired design, and assumptions matter.

When assumptions are doubtful, consider robust or nonparametric alternatives.

COMPARISON

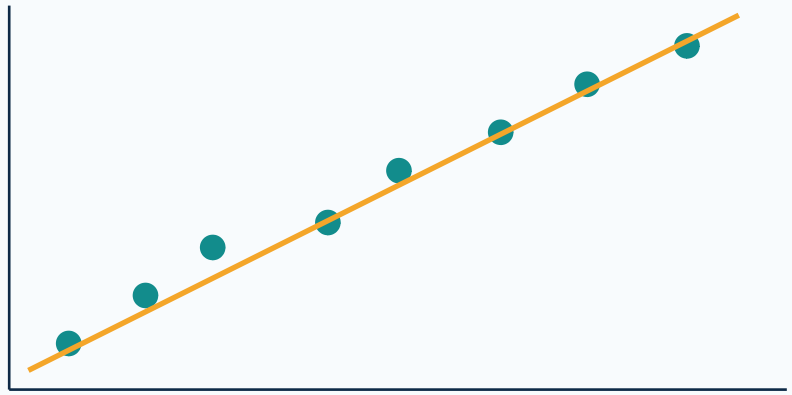
Parametric vs Nonparametric Methods

Feature	Parametric methods	Nonparametric methods
Typical assumption	Often assume a distribution such as normality	Fewer distributional assumptions
Data level	Usually interval/ratio outcome data	Often ordinal, ranked, skewed, or small-sample data
Examples	t-test, ANOVA, Pearson correlation, linear regression	Mann–Whitney U, Wilcoxon signed-rank, Spearman correlation
Strength	Powerful when assumptions fit	Useful when assumptions are doubtful
Limitation	Can mislead if assumptions are violated	May lose information by using ranks

Correlation and Regression

Correlation
Measures direction and strength of association between two variables. It does not establish causation by itself.

Regression
Models how one or more predictors relate to an outcome and can support prediction.



A positive relationship: as study time increases, test scores tend to increase.

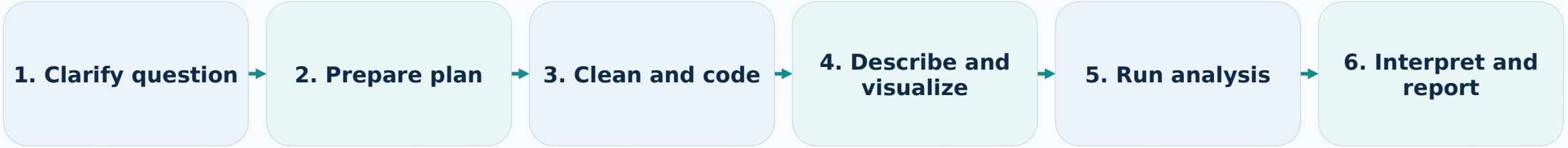
Correlation summarizes association.

Regression estimates and predicts an outcome.

Causal claims require strong design and theory.

PRACTICAL WORKFLOW

Step-by-Step Analysis Process



1
Start with the question, not software.

2
Check data quality before tests.

3
Use descriptive statistics first.

4
Interpret using theory and limitations.

BEFORE ANALYSIS

Data Preparation and Cleaning

TYPICAL TASKS

Screen missing data, duplicates, impossible values, and entry errors.

Code categorical variables consistently.

Reverse-code items when needed and document every change.

Check outliers and decide transparently how to handle them.

DOCUMENTATION HABITS

Keep the raw dataset unchanged.

Create a data dictionary with variable names and coding rules.

Record cleaning decisions in an analysis log.

Use reproducible scripts when possible.

APPLICATIONS

Practical Examples Across Disciplines

Discipline	Possible data	Possible analysis
Social sciences	Survey responses on civic participation	Descriptive statistics, correlation, regression
Business & management	Sales, customer ratings, advertising spend	Trend analysis, group comparison, regression
Education	Test scores before and after an intervention	Paired t-test, effect size
Health sciences	Blood pressure, treatment group, recovery time	Group comparison, confidence intervals
Psychology	Stress scale, sleep hours, attention score	Correlation, ANOVA, regression
Information technology	Response times, error rates, satisfaction	Charts, A/B testing, regression

Detailed Research Scenario

Element	Example
Research topic	Online formative quizzes and undergraduate statistics achievement
Research problem	Students often struggle with statistics concepts despite traditional lectures.
Research question	Do weekly online quizzes improve final exam scores?
Participants	Two sections of undergraduate research methods students
Data collection	Final exam scores, quiz participation records, prior GPA
Analysis method	Descriptive statistics; t-test or regression controlling for prior GPA
Expected interpretation	Higher quiz-group scores with a meaningful effect size may support learning, but causality depends on design quality.

STRENGTHS

Advantages of Quantitative Data Analysis

Precision
Measures patterns and differences numerically.

Comparability
Allows comparison across groups, time, and studies.

Generalization
Supports wider claims when sampling is appropriate.

Replicability
Procedures can be documented and repeated.

Efficiency
Large datasets can be analyzed quickly.

Decision support
Guides evidence-based policies and programs.

Limitations and Challenges

Numbers may simplify complex human experiences or social contexts.

Poor measurement can produce precise-looking but invalid results.

Statistical association does not automatically prove causation.

Results can be biased by sampling problems, missing data, or inappropriate tests.

Overemphasis on p-values can hide practical meaning and uncertainty.

Software output can be misunderstood if assumptions and context are ignored.

Critical thinking is part of quantitative analysis.

AVOID THESE

Common Mistakes

Mistake	Why it is a problem	Better practice
Choosing tests after seeing results	Encourages biased conclusions	Plan analysis before data collection
Ignoring measurement scale	Can produce invalid summaries or tests	Match methods to data type
Reporting only p-values	Hides magnitude and uncertainty	Report effect size and confidence interval
Treating correlation as causation	Overstates what data can prove	Use careful wording and design evidence
Not checking assumptions	Can make results misleading	Screen data and justify method choice
Overcrowding tables	Makes results hard to understand	Report only necessary values clearly

Best Practices

Begin with a clear research question, hypothesis, and analysis plan.

Use valid and reliable measurement instruments when possible.

Inspect data visually and numerically before inferential tests.

Report descriptive statistics, test results, effect sizes, and uncertainty clearly.

Explain why the selected method fits the design, variables, and assumptions.

Keep raw data, cleaned data, codebook, and analysis decisions organized.

Interpret results using theory, context, limitations, and ethical responsibility.

COMPARISON TABLE

Descriptive vs Inferential Analysis

Feature	Descriptive analysis	Inferential analysis
Main purpose	Summarize the data you observed	Draw cautious conclusions about a wider population
Typical outputs	Frequencies, percentages, mean, median, charts	p-values, confidence intervals, estimates, test statistics
Key question	What does this dataset show?	What can this sample suggest about the population?
Risk if misused	Overlooking patterns or outliers	Overgeneralizing from weak or biased samples
Example	Average satisfaction is 4.1 out of 5	Satisfaction differs significantly between service groups

Ethical Considerations

Privacy & confidentiality
Remove identifiers, protect datasets, and avoid unnecessary personal data.

Informed consent
Explain what data will be collected and how it will be analyzed.

Transparency
Report methods, exclusions, coding, assumptions, and limitations honestly.

Bias awareness
Consider sampling, measurement, and algorithmic bias.

Academic integrity
Do not manipulate data, cherry-pick results, or hide inconvenient findings.

Respectful reporting
Avoid stigmatizing groups or overstating evidence.

PRACTICE TASK

Activity or Classroom Exercise

Activity objective
Practice matching research questions, variables, and analysis methods.

Instructions
For each mini question, identify the outcome variable, predictor or group variable, measurement scale, and a suitable descriptive or inferential method.

Mini question	Likely method
Do students in two groups differ in average study hours?	Group comparison / t-test
Is sleep duration related to stress score?	Correlation or regression
What percentage of students prefer online learning?	Frequencies and percentages

Expected outcome: students can justify a basic analysis choice using the research question and variable types.

Discussion Questions and Knowledge Check

Why should researchers define variables before collecting data?

When might the median be more useful than the mean?

What is the difference between statistical significance and practical importance?

Why can correlation alone be misleading when making causal claims?

Which measurement scale has ordered categories but unequal gaps?

What does a p-value assume when it is calculated?

Which test examines association between two categorical variables?

REVIEW

Answer Key, Key Takeaways, and Conclusion

Item	Answer
Ordinal scale	Ordered categories with unequal gaps
p-value assumption	Calculated under the assumption that the null hypothesis is true
Two categorical variables	Chi-square test of independence
Effect size	Shows magnitude or practical strength of a result

Quantitative analysis turns numerical data into organized evidence.

Good analysis begins with research questions, variables, measurement scales, and design logic.

Descriptive statistics summarize observed data; inferential statistics estimate uncertainty.

Ethical, transparent, and well-documented analysis strengthens research credibility.

Conclusion: Quantitative analysis is a disciplined reasoning process that helps researchers make clear, cautious, evidence-based claims.

References and Thank You

Agresti, A. (2018). Statistical methods for the social sciences (5th ed.). Pearson.

American Psychological Association. (2020). Publication manual of the American Psychological Association (7th ed.). American Psychological Association.

Creswell, J. W., & Creswell, J. D. (2023). Research design: Qualitative, quantitative, and mixed methods approaches (6th ed.). SAGE.

Field, A. (2018). Discovering statistics using IBM SPSS Statistics (5th ed.). SAGE.

Gelman, A., & Hill, J. (2007). Data analysis using regression and multilevel/hierarchical models. Cambridge University Press.

Pallant, J. (2020). SPSS survival manual: A step by step guide to data analysis using IBM SPSS (7th ed.). Routledge.

Tabachnick, B. G., & Fidell, L. S. (2019). Using multivariate statistics (7th ed.). Pearson.

Tukey, J. W. (1977). Exploratory data analysis. Addison-Wesley.

Thank You

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